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A MULTIDIMENSIONAL ANALYSIS OF PHYSIOLOGICAL AND MECHANICAL VARIABLES AMONG ARCHERS OF DIFFERENT LEVELS OF EXPERTISE

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ABSTRACT

The present study investigates the various physiological and mechanical techniques employed by archers of varying skill levels. A total number of four archers two females (gold medalist and non-medalist) and two males (expert and novice) participated in the study in two separate experiments. A sum of four shimmer sensors were used to examine, compare and differentiate the postural balance, movement of the bow, muscular activations of the muscle flexor digitorum superficial and muscle extensor digitorum as well as the heart rate variability of the archers. The results revealed that elite and medalist archers are better in controlling their postural sway, reducing the movement of their bows, have greater activation of muscle extensors. Both medalist and elite archers maintained a lower heart rate, hence achieved consistency and maximum scores as opposed to the non-medalist and novice archers.

Keywords: archery; muscle activations; heart rate; bow movement; postural sway.

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1. INTRODUCTION

Archery is a sport that involves driving arrows with a bow to the target in the course of shooting [1]. It can also be seen as a relatively still sport that requires strength and endurance of the upper body, specifically the forearm and the shoulder girdle. In the game of archery, competitors contest for points by shooting a set number of arrows within a stipulated time frame. Traditionally, archery has been utilized for chasing and battle. Presently, it has turned into a recreational activity as well as competitive sports at different levels of expertise and gender.

The technical skill of archery is commonly comprehended to contain eight segments: stance, set, nocking, set up, drawing, full draw, release and follow through [1-8]. In the event that these are classified as indicated by Meinel's stage structure of action, stance to nocking is the preliminary stage [1, 3], set up to release is the fundamental stage [4, 7] and follow through is the finishing stage [2, 8]. Past study with respect to bows and arrows has especially centered around full draw and release [6-7], by concentrating on electromyograms [3-7], heart rate [8-9] or brain waves [9-10]. Aiming time and its relationship with archery shooting scores were previously analyzed [8]. It was stated that although aiming time was longer for low scoring shots than high-scoring shots for some competitors, there was no marked distinction. It ought to be noticed that shooting contained eight progressive segments as specified above and the characteristic elements of stages other than aiming time are yet to be thoroughly inspected.

The nature of archery as a static and non-contact sport requires the archer to pay attention and consider the interactions of both the physiological and mechanical variables, which either directly or indirectly determine the outcome of performance in the sport. It has been demonstrated by the previous researchers that the ability of the archer to control his or her postural sway, heart rate and activation as well as relaxation of the relevant muscles resulted in shooting consistency and consequently lead to higher archery scores [3-7]. Despite attempts by the researchers to offer insights into the aforementioned indicators, there are still relatively few studies examining the collective interactions of the physiological and the mechanical variables as well as the comparative techniques employ by archers of different levels of expertise. Thus, the current study endeavours to compare and differentiate the postural balance, movement of the bow, muscular activations of the muscle flexor digitorum superficial and muscle extensor digitorum as well as the heart rate of the medalist versus non-medalist and expert versus novice archers during archery performance.

2. METHODOLOGY

2.1. Participants

The participants of the present experiment involved a gold medalist female archer who has just clinched a gold medal during the just concluded inter-state archery Malaysian championship (SUKMA tournament held in Sarawak). She is 20 years old, 77 kg in weight, 155 cm in height and possessed eight years of archery shooting experience while a non-medalist female archer who is 18 years old, 56 kg in weight, 154 cm in height and has six years of archery shooting experience were recruited for the first stage of the experiment. However, in the second stage of the experiment, an elite male archer who is 25 years old, 97 kg in weight, 176.4 cm in height and acquired a 12 years of archery shooting experience with many medals accredited to his name was selected. Also, a novice male archer who is 20 years old, 76 kg in weight, 170 cm in height and obtained one year of archery shooting experience were used for the second stage of the experiment. Written approval for the experiment was obtained, and all the archers signed consent forms. All the procedures, protocol and apparatus for this study were permitted by the Research Ethics Board of the Terengganu Sports Institute (ISNT) with a reference number 04-04/T-01/Jid 2.

2.2. Experimental Protocol

The experimental protocol in the current study was implemented in two stages. In the first stage (Medalist vs. Non-medalist) archers were instructed to shot a total of six arrows (one-end). A simulated shooting board was organized at the University Sultan Zainal Abidin (UnisZa) and all the archers were permitted to shoot three arrows for trial to familiarize themselves with the sensors before the actual shooting. The archers shot the arrows over a distance of 50m, which is considered appropriate across all the archer's age ranges and shooting experience. The selected parameters were observed during the aiming, stance and the releasing phases of the arrows. Similarly, in the second stage (elite versus novice) archers were also observed during the process so as to enable the researcher to compare and differentiate the selected physiological indicators between the archers.

2.3. Data Collection Procedure

A total of 4 IMUs Shimmer sensors were used in the present experiment to compare and distinguish the postural balance, movement of the bow, muscular activations of the muscle flexor digitorum and extensor digitorum as well as the heart rate of the archers. To measure the postural sway, an accelerometer was firmly attached to the pelvic region of the archers as suggested by previous researchers to be the appropriate area when a center of mass is to be determined [11]. To ascertain the movement of the bow, a shimmer sensor was attached to the hand of the archer holding the bow using a glove to hold the accelerometer tightly. However, bipolar electrodes were connected to the sensor by enabling the heart rate detector to determine the heartbeat of the archers from the wrist. Similarly, two shimmer sensors were attached to the left muscle extensor digitorum and the right muscle flexor digitorum to obtain Electromyography (EMG) signals during the performances of the archery related movements described previously. All the data were streamed in real time at a sampling rate of 51.2 Hz using an Android phone and transmitted via Bluetooth for further analysis. The areas of all the sensors attachments in the body are shown in Fig. 1.

3. RESULTS AND DISCUSSION

Fig. 2 reveals the comparative analysis of extensor digitorum muscular activation between medalist and non-medalist archers during the archery shooting process. It can be detected that there was a higher muscular activation recorded from the medalist archer (red colour) when compared with the non-medalist (black colour). From the graph, it can be seen that the muscle extensor of the medalist archer is highly activated throughout the aiming and the releasing phases as opposed to the non-medalist archer. Therefore, this result indicated that the muscle extensor activation is higher in medalist archers during both aiming and releasing the arrow phases. The result from this experiment is supported by the previous researchers who reported that muscle extensors serve as the supportive muscle during the performance of archery and therefore it is expected to be more activated for the achievement of the higher score because it helps to stabilize the bow [12].

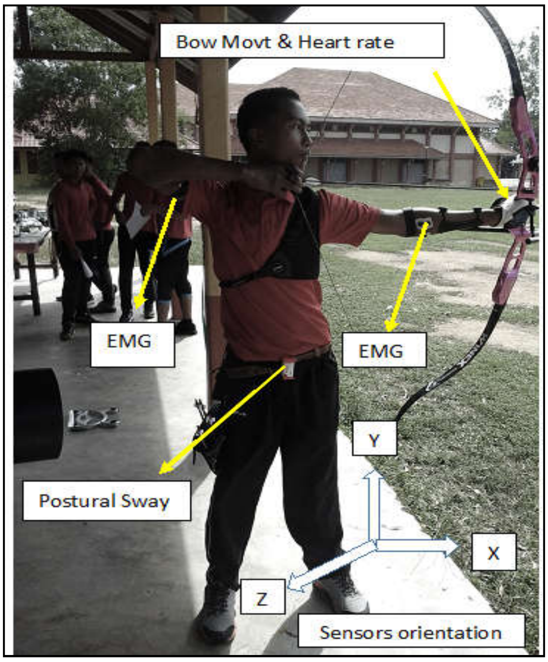

Fig.1. IMUs sensors' location attachments in the archer's body

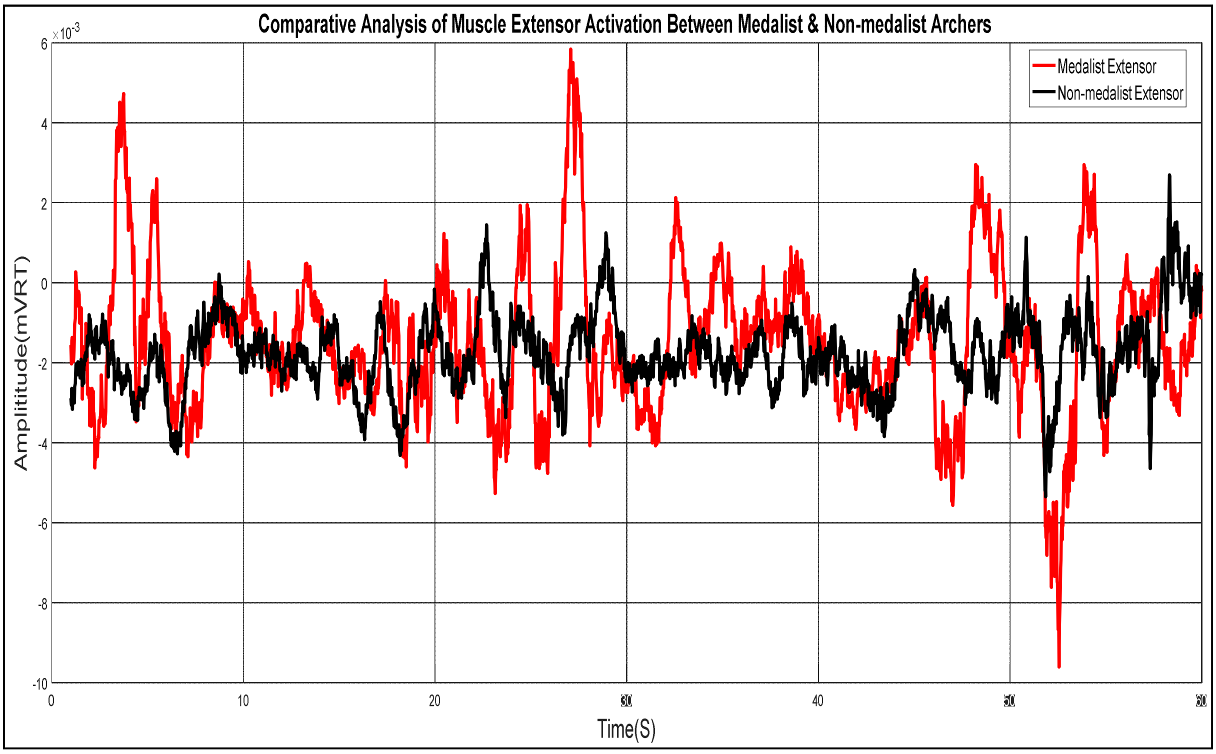

Fig.2. Comparative analysis of the muscle extensor activation between medalist and non-medalist archers (Experiment 1A**)**

Fig. 3 discloses the comparative analysis of flexor digitorum muscular activation between medalist and non-medalist archers during the archery shooting process. It can be witnessed that there was a slightly higher muscular activation documented from non-medalist archer (brown colour) when compared with the medalist archer (blue colour).This finding is consistent with the findings of previous researchers who observed that during the release of the arrow the flexor muscle digitorum of skilled archers is significantly relaxed and thus served as the lowest activated muscle during the process [13].

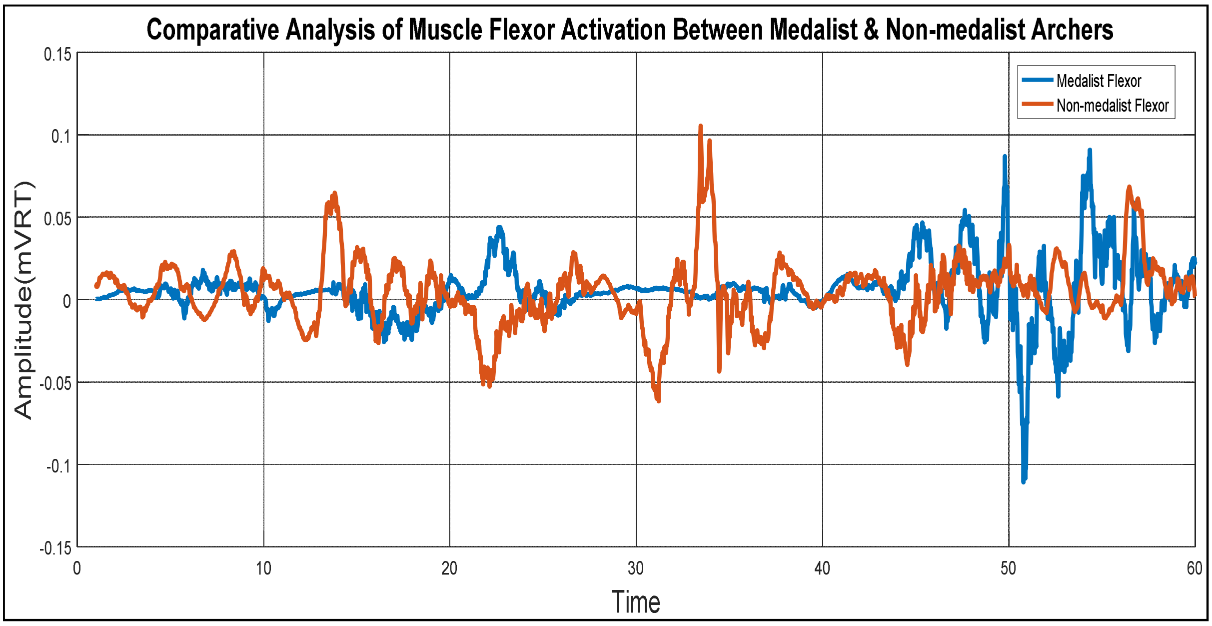

Fig.3. Comparative analysis of flexor digitorum muscular activation between medalist and non-medalist archers (Experiment 1B)

Fig. 4 reveals the comparative analysis of bow movement during the archery shooting process. It can be witnessed from the figure that there were some movements while holding the bow in both archers. However, the movement of the bow of the medalist archer (black colour) is observed to be lower as opposed to the non-medalist (brown colour). Based on this result, it can be agreed that the movement of the bow among the medalist archers is lower when compared to the non-medalist as indicated by the previous researchers [14].

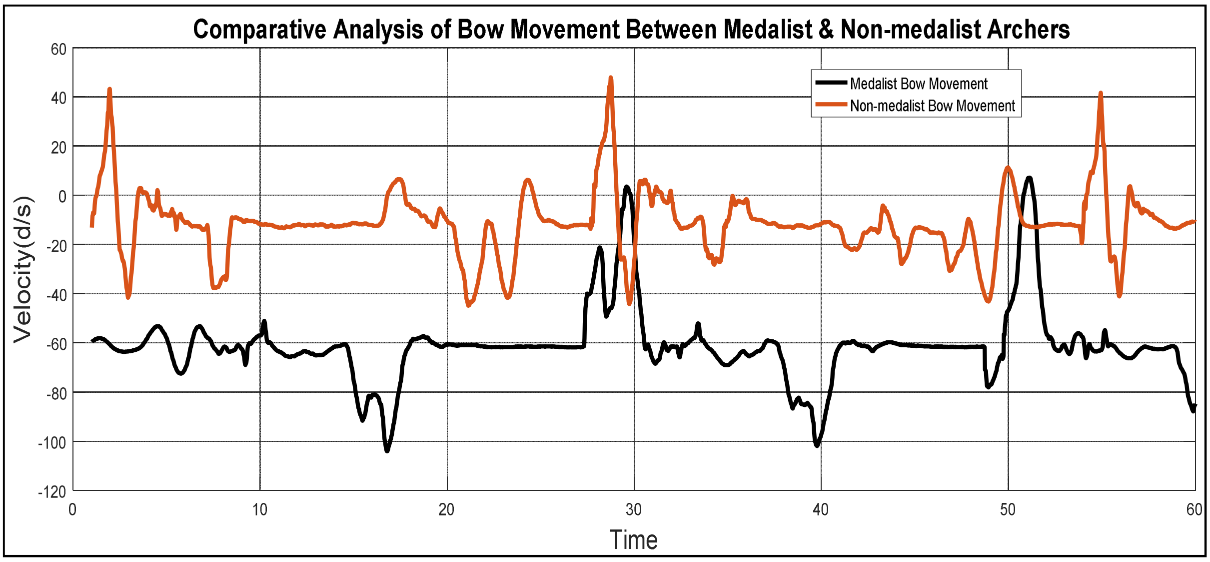

Fig.4. Comparative analysis of bow movement between medalist and non-medalist archers (Experiment 1C)

Fig. 5 displays the stability test conducted to compare the ability of the archers to maintain balance. It can be observed from the illustration that the medalist archer (blue colour) has a considerable less movement while shooting the arrow when compared to the non-medalist archer (brown colour). It can be seen from the figure that the pattern of the movement detected from the medalist archer has followed linear and some form of uniformity which revealed that the movement of the archer was more stable compared to that of the non-medalist archer. Based on this experiment, it can be concluded that the medalist archers are more stable and can control their sway while shooting the arrow as opposed to the non-medalist.

Fig. 6 projects a comparative analysis of the heart rate and the consistencies of the archery scores between Medalist and Non-medalist archers. From the figure, it can be witnessed that the heart rate recorded from the archers does not follow the same level. The heart rate of the medalist archer (black colour) is found to be lower when compared to the heart rate of the non-medalist archer (red colour). However, it can also be observed from the figure that the lower the heart rate, the higher and more stable the score recorded. The archery score of the medalist archer is observed to be stable and higher due to the lower heart rate while the scores of the non-medalist archer are found to be fluctuated and lower as opposed to the medalist. The result from this heart rate revealed that the lower the heart rate of the archer during the aiming and releasing stages of the arrow the more stable and higher the scores. This finding is in agreement with the findings of the previous researchers who reported that heart rate of the elite archers is correspondingly lower as compared to non-elite [15].

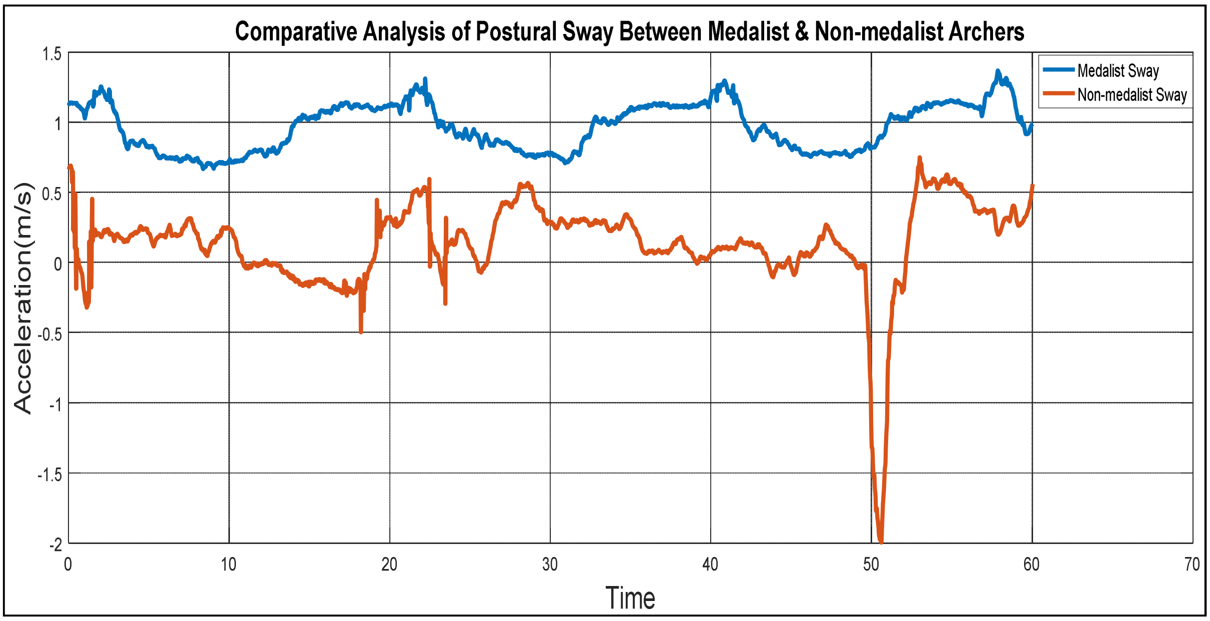

Fig.5. Comparative analysis of postural sway between medalist and non-medalist archers (Experiment 1D)

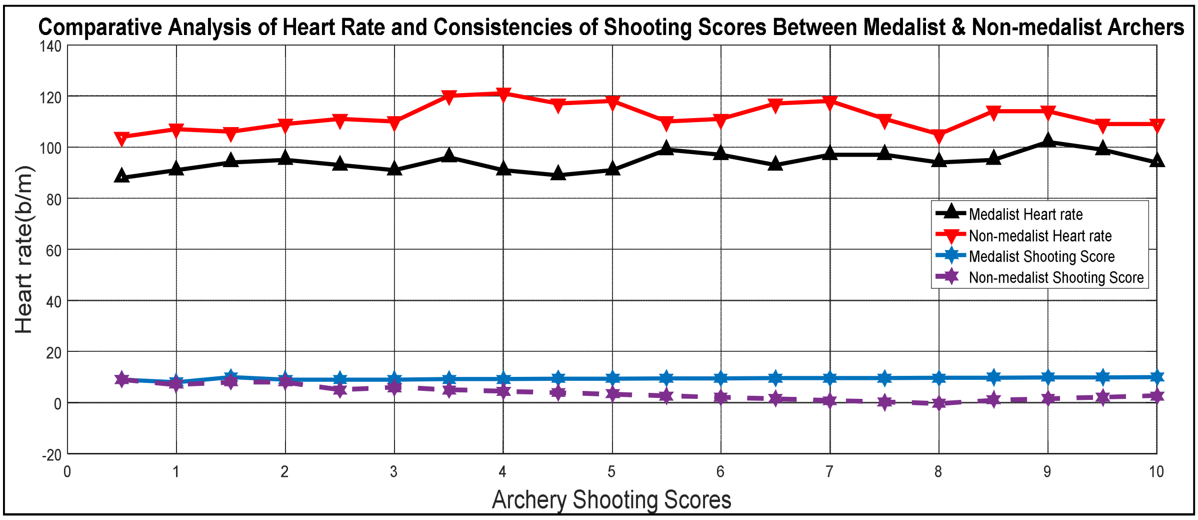

Fig.6. Comparative analysis of heart rate and the consistencies of the archery scores between medalist and non-medalist archers (Experiment 1E)

Fig. 7 reveals the comparative analysis of extensor digitorum muscular activation between novice and elite archers during the archery shooting performance. It can be observed that there was a higher muscular activation recorded from the elite archer (red colour) when compared with the novice (blue colour). Therefore, this result indicated that the muscle extensor activation of the elite archer is the higher activated muscle during both aiming and releasing the arrow phases. It has been documented that during archery performance, an archer pushes the bow with stretched arm which is statically held in the bearing of the target, while the other arm applies a dynamic pulling off the bowstring from the earliest starting point of the drawing stage until the discharge is progressively executed [16]. Hence, the contraction of the muscle extensor during the release of the bowstring is essential for accurate and higher scoring in archery.

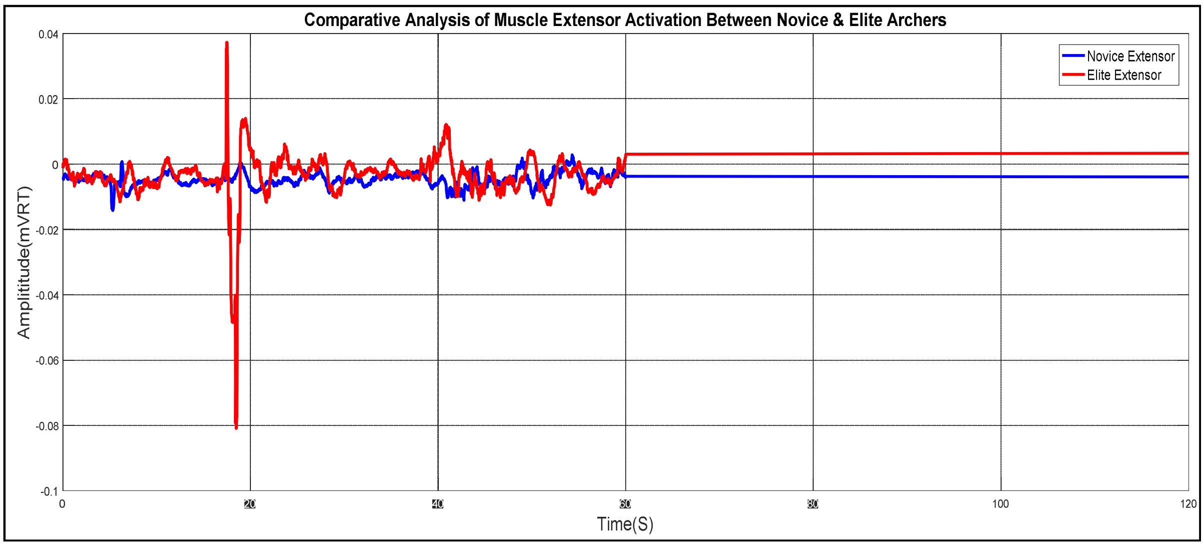

Fig.7. Comparative analysis of the muscle extensor activation between novice and elite archers (Experiment 2A)

Fig. 8 reveals the comparative analysis of flexor digitorum muscular activation between novice and elite archers during the archery shooting performance. It can be seen that there was a greater muscular activation documented from the novice archer (black colour) when compared with the elite archer (red colour). This finding is consistent with the findings of previous researchers who observed that during the release of the arrow the flexor muscle digitorum of skilled archers is significantly relaxed and thus served as the lowest activated muscle during the process [17]. However, a gradual relaxation of the muscles is observed among both archers. This finding is in concord with the findings of the previous researchers who also discovered that archers presented a progressive relaxation of the muscle flexor digitorum superficialis after the release of the arrow [5].

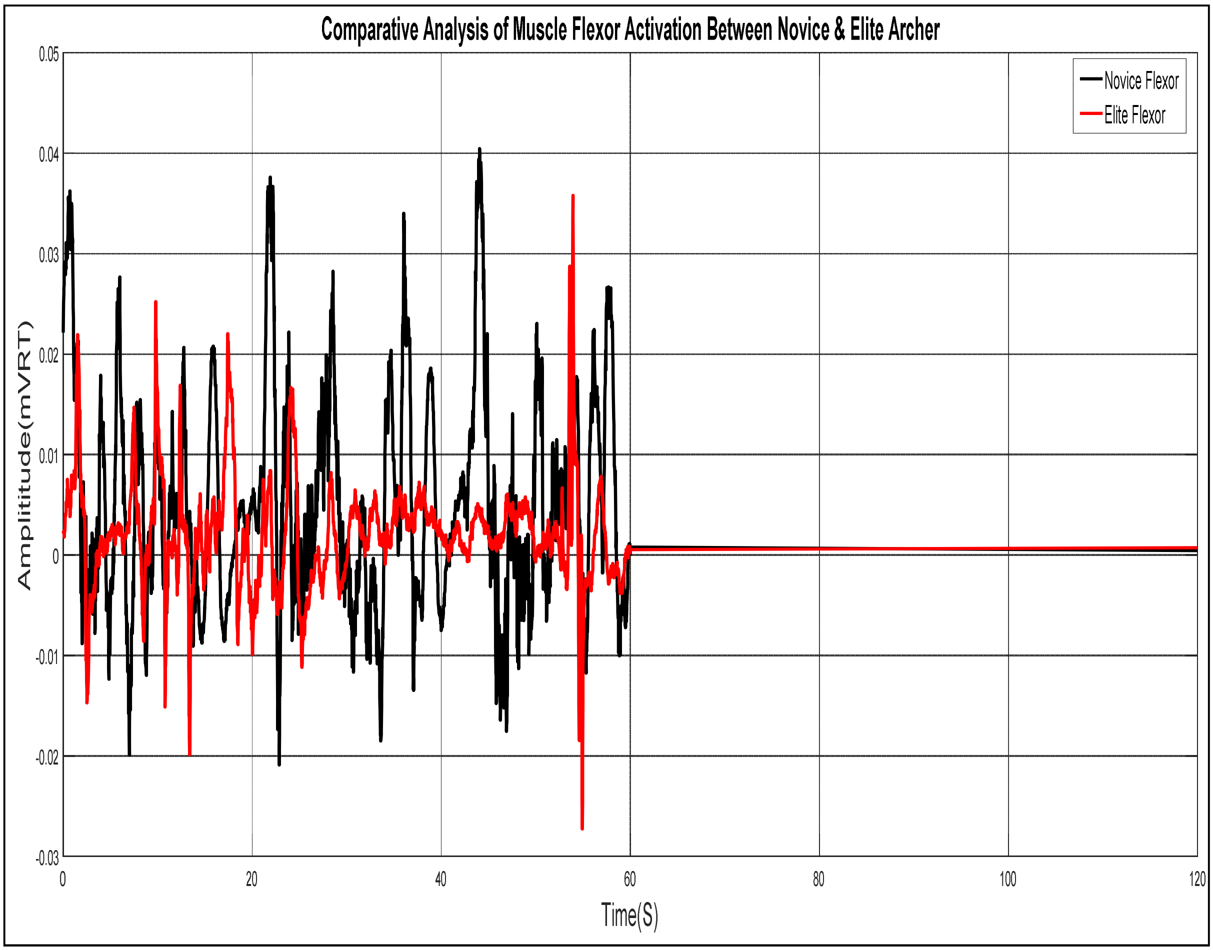

Fig.8. Comparative analysis of flexor digitorum muscular activation novice and elite archers (Experiment 2B)

Fig. 9 shows the stability test conducted to compare the ability of the archers to maintain balance. It can be detected from the illustration that the elite archer (brown colour) has a significant less movement while shooting the arrow when compared to the novice archer (brown colour). Based on this experiment, it can, therefore, be concluded that the elite archers are more stable and can control their sway while shooting the arrow as opposed to the novices. It has been reported that one of the vital subcomponents in keeping up shooting accuracy is aiming stability [18]. Achieving a high level of postural stability through aiming intensifies the aiming stability of an archer. Aiming stability characterized as the central form of aiming, guarantees continuous flight direction to the objective. This specific circumstance offers effect to the performance result. Moreover, it is reported that the elite archer's pointing locus is much slighter as opposed to the novice archers [19].

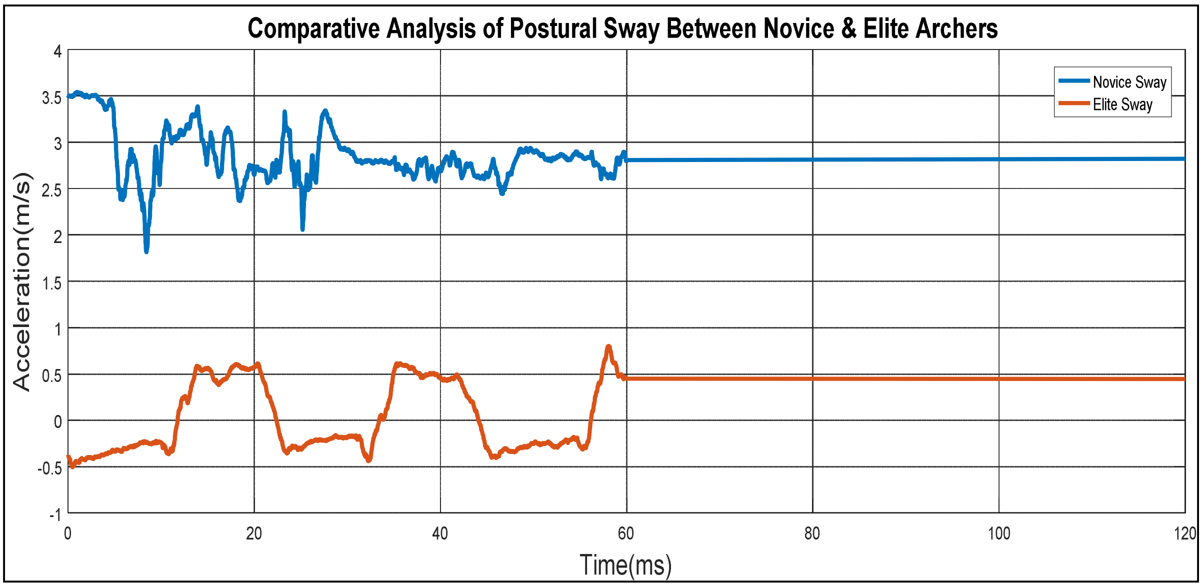

Fig.9. Comparative analysis of postural sway between novice and elite archers (Experiment 2C)

Fig. 10 reveals the comparative analysis of bow movement during the archery shooting process. It can be seen from the illustration that the movement of the bow of the elite archer (brown colour) is detected to be lower as opposed to the novice (blue colour). Based on this result, it can be agreed that the movement of the bow among the elite archers is lower when compared to the novice and consequently lead to the elite archers having a greater score as indicated by the previous researchers [20].

Fig. 11 projects a comparative analysis of the heart rate and the corresponding archery scores between novice and elite archers. From the figure it can be observed that the heart rate of the elite archer (red colour) is found to be lower when compared to the heart rate of the novice archer (blue colour). However, it can also be observed from the figure that the lower the heart rate, the higher and more stable the score recorded. The archery score of the elite archer is seen to be stable and higher due to the lower heart rate while the scores of the novice archer are found to be fluctuated and lower as opposed to the medalist. The result from this heart rate revealed that the lower the heart rate of the archer during the aiming and releasing stages of the arrow the more stable and higher the scores. This finding is in agreement with the findings of the previous researchers who reported that heart rate of the elite archers is correspondingly lower as compared to the novice [21].

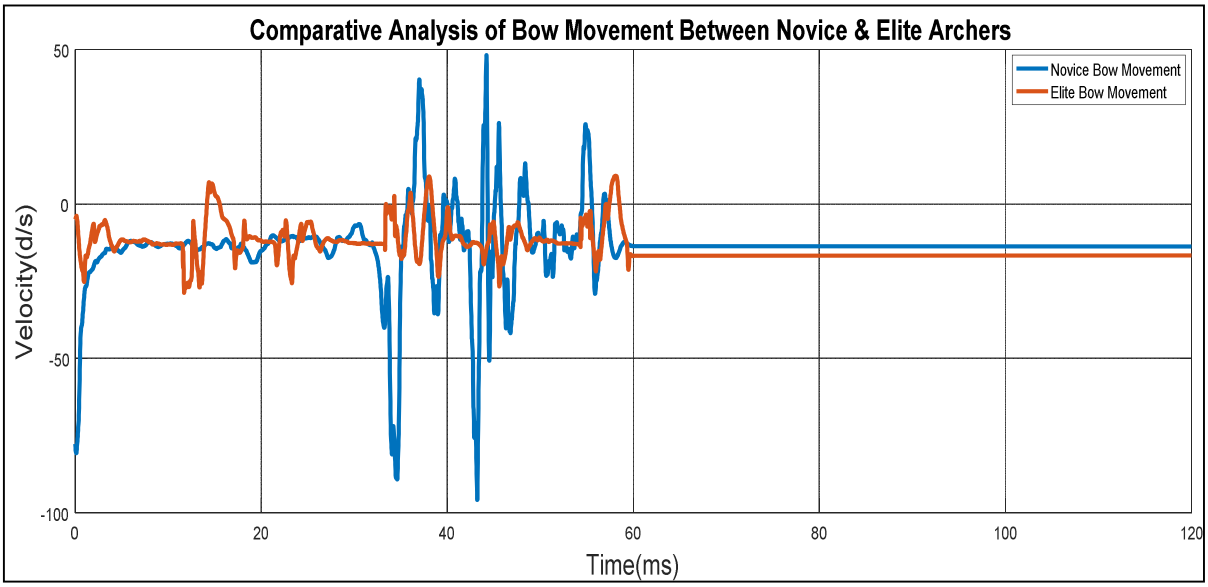

Fig.10. Comparative analysis of bow movement between novice and elite archers (Experiment 2D)

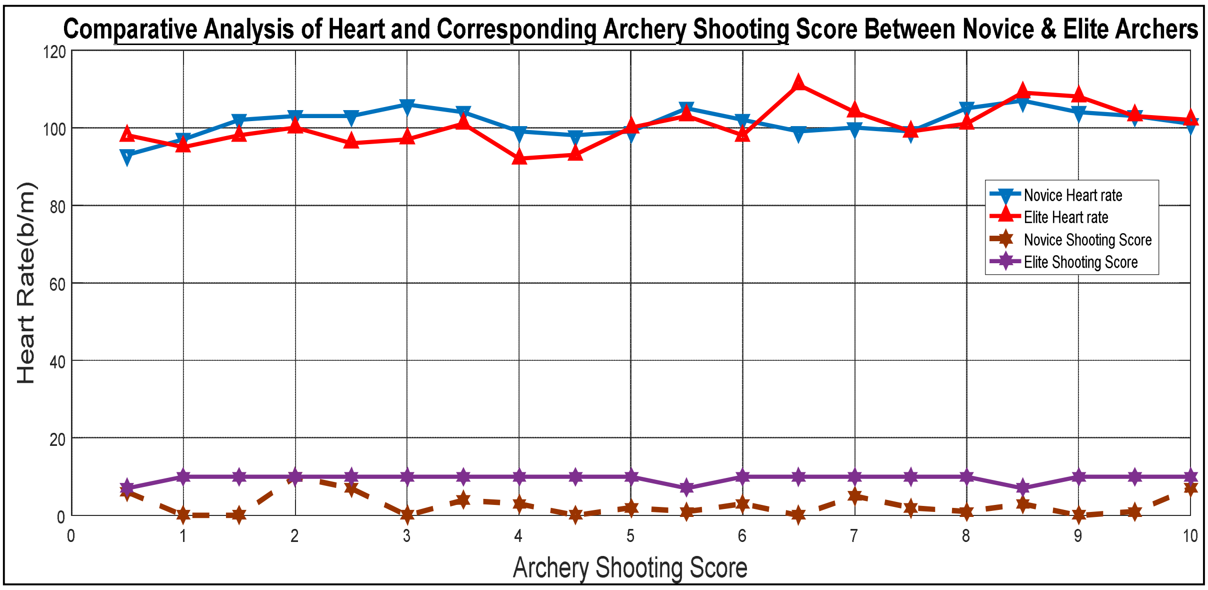

Fig.11. Comparative analysis of heart rate and the corresponding archery score between novice and elite archers (Experiment 2E)

4. CONCLUSION

The current experiment has successfully evaluated postural sway, bow movement, muscular activation as well as heart rate and shooting scores attributed to the game of archery in two different stages of the experiment. From the both analysis, the findings have shown that there are differences between medalist and non-medalist as well as elite and novice archers in relation to the all the performance indicators measured in the present experiment. The results have revealed that elite and medalist archers are better in controlling their postural sway, reducing the movement of their bows, have greater activation of muscle extensors which implies that they avoid over-gripping the bow and presented less activation of muscle flexors which indicated that they tend to relax their flexors while aiming and releasing the arrows. Nevertheless, the results of the experiment have further revealed that both medalist and elite archers maintained a considerable lower heart rate and hence achieved maximum and consistency of scores as opposed to the non-medalist and novice archers. The findings from the current experiment will be useful to coaches in re-structuring their training programme through paying attention to the aforementioned performance indicators, which will go a long way in addressing challenges faced by non-medalist and novice archers and also will help to serve as guide for the optimization of performance of both medalist and elite archers for a better delivery of performance.

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